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Application of power electronic components to control parameters and switching of compensation devices on power networks

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Abstract. In practice, consumption devices are not only resistive but also reactive and this reactance varies with time. Therefore, grid voltage is not stable and coefficients always change in spite of using Automatic Reactive Power Regulator. To regulate voltage and cosφ in an expected range, it is necessary to change the parameters of regulators as the loads change.

Determining regulated threshold and time of switching and changing parameters of regulators are controlled by microprocessor and power electronic components. Microprocessor provides a flexible energy control and a high automation ability to ensure a high reliability and stability of the system.

This paper presents how to determine the flexible regulated threshold to ensure the quality of supply energy..

1. Introduction

The power network configuration is shown in Figure 1. The source of supply to the network is the three-phase three-winding power transformer 500/220/110kV or the high-voltage busbar of the power plant supplies power to loads through primary distribution lines configured as open ring or radial network whose voltage should be stepped down to 35kV, 22kV, 10kV or 6kV. If the voltage rated at 35kV, there should be 35kV distribution lines supply power straight to the facilities and stepped down to 22kV, 10kV or 6kV by local step-down transformers. From the 22kV, 10kV or 6kV primary open ring or radial distribution lines are connected [1-3]. To supply low-voltage loads, distribution transformers, which stepped voltage down again to 380/220V, are connected to these lines. Behind these transformers, consumers will be supplied directly through radial circuits.

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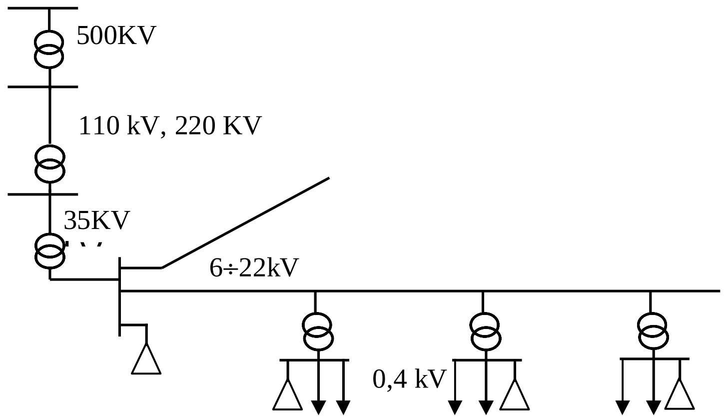

Fig. 1. Diagram of power network.

For this network, the power factor (cosφ) and reactive power compensation is considered for each voltage level. According to surveys of Power Transmission Companies and Utilities, power factor for each voltage level as follow:

- For 35kV level: power factor is around 0.8 at peak load, 0.99 at off-peak load. Thus, the power factors measured at sending ends of 22kV, 10kV or 6kV feeders are quite high which are similar to those of high-voltage transmission lines.

- At receiving ends of 22kV, 10kV or 6kV feeders, measured power factors are lower than the sending ends. Because the distribution transformers 22(10 or 6)kV/0.4kV are underload in some cases, the power factors measured at the transformers' secondary busbars are lower. Further, power factors measured at terminals of appliances such as fans, air-conditioners, refrigerators, Neon tubes... are even lower because of consuming a lot of reactive power. Therefore, not only the compensation devices should be installed on the primary side but also on the the secondary side.

Commonly, compensation level was calculated according to the loads (imposible maximum power of loads) [4,5]. In practice, the power of loads vary depending on demand of comsumption, result in varying voltage profile and power factor, therefore effecting power supplying quality. Further more, reverse reactive power caused by over-compensation make power losses on the network increase. Thus, it is necessarily to control parameters and switching compensation devices according to the changing of loads. The controlling of compensation devices could be implemented by power electronics structures controlling the firing angle of thyristor.

In the next section, we introduce a power electronic structure to control firing angle α of thyristor.

2. Power electronic structure for controlling firing angle α of thyristor

2.1. Controlling block diagram

The controlling circuit block diagram of thyristor shown in Figure 2.

Main functions of the circuit as follow [6,7]:

- Flexible determining the time to issue controlling pulses in the positive half-cycles of applied voltage to thyritor valves.

- Generate firing pulses to fire thyristor valves. The pulses have amplitudes from 2 V to 10 V commonly, pulse width t_x=20÷100 s for rectifiers or two parallel-connected pair of thyristor valves.

Pulse width is calculated from the formula: $t_x = \frac{I_{con}}{di/dt}$

Where: I_{con} is the continuous current of thyristor valves.

di/dt is the incremental change in load current.

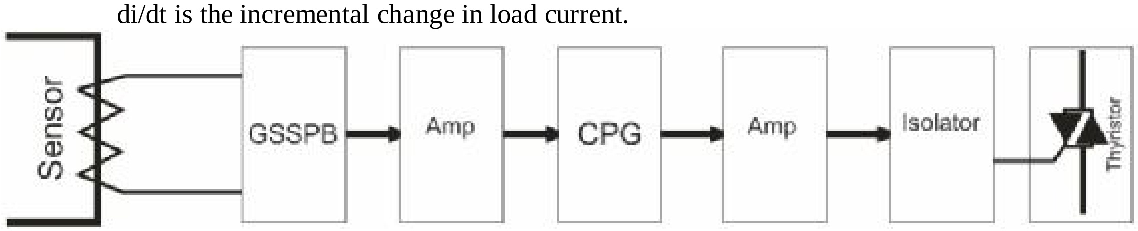

Fig. 2. The block diagram of the electronic power circuit controls firing angle α.

A structure of thyristor controlling circuit comprises four main block:

- GSSPB - Generating standard sample pulse block (sensor): to issue standard sample pulse then will be synchronized with controlling voltage signal to fire thyristor valves in need.

- Determining controlling pulses according with sample pulses CPG (Controlling Pulses Generator): to issue controlling pulses according with sample pulses to fire thyristor valves.

- Pulse Amplifier: to amplify both sample pusles and controlling pulses to fire desired thyristor valves.

- Isolator: to isolate the power circuit from controlling circuit.

By changing in DC voltage signal U_{dk} we could change the firing angle.

2.2. Controlling principles

As illustrated in Figure 3, across controlling principle is applied to determine the time of issueing pulse in the positive half-cycles of voltage signal applied to thyristor valves.

According to this principle [4,5], there are two voltage signals fed to comparision block:

- The input sinusoidal wave form voltage is converted to cosine wave of voltage at the output of Generating standard pulses block.

- The controlling voltage signal is changable DC voltage.

If the sample voltage is $u_{sample} = U_m \sin\omega t$ than $U_c = U_m \cos\omega t$

The firing angle α is calculated from the equation: $U_m \cos\alpha = U_{control}$

Hence: $\alpha = \arccos(U_{control}/U_m)$

- If $U_{control} = U_m$ then $\alpha = 0$

- If $U_{control} = 0$ then $\alpha = \pi/2$

- If $U_{control} = -U_m$ then $\alpha = \pi$

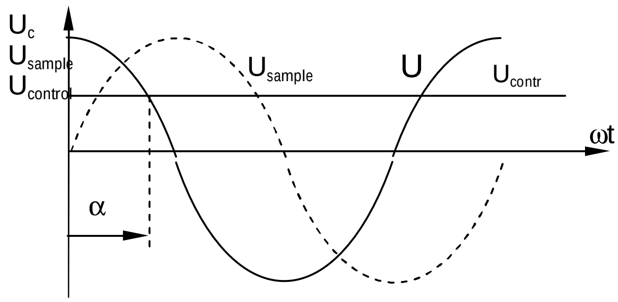

Fig. 3. Across controlling principles.

For this analysis, if we control the variation of voltage changes U_{dk} from value of $-U_m$ to $+U_m$ we could obtain the changing in firing angle α from 0 to π.

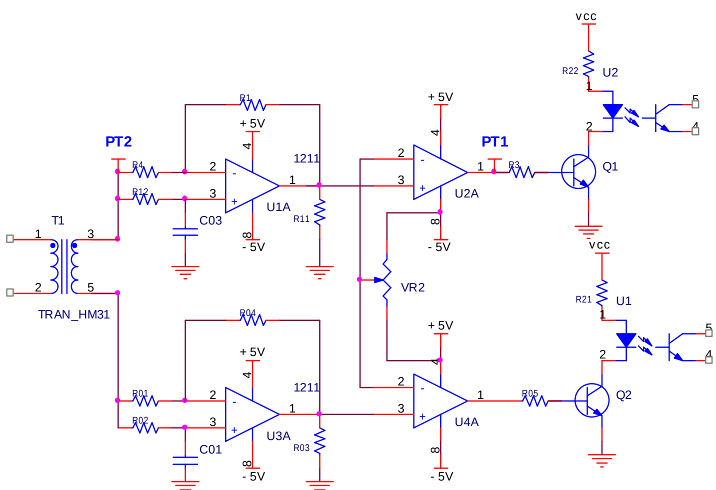

Fig. 4. Simulation circuit (measure the waveform in pulse generator controlled by the sample).

The circuit consists of two chanels for switching two thyristors Q1 and Q2. Each chanel consists of three blocks. They are cosωt funtion generating block, comparing block and amplifier block.

- cosωt funtion generating block for two chanels consists of U1A, U3A, resistor R and capacitor C.
- comparing block for channels consists of U2A, U4A and VR2.
- amplifier block for channels consists of transistors Q1, Q2 and resistors R22, R21, R3, R05 and U1,U2.

The circuit works based on the principle of control according to the function *arccos*. This circuit uses operation amplifiers (ICs) for generating the function cosωt and comparing the signs of the inputs of these ICs. The outputs of function generating block are fed to the positive inputs In(+) of U2A and U4A. Their negative inputs In(-) are connected to the battery [±5V] via variable resistor VR2. The control voltage fed IN(-) is according to adjusting variable resistor VR2. The outputs of comparing block are fed to the base terminals of transistors Q1 and Q2 via the resistors R3 and R05 for limiting current. The control pulses are insulated from U1 and U2 by using auto-couplers.

Some forms of pulses measured at (PT1) point at the above circuit with the different values of $U_{control}$ are presented in the figure 5.

Pulses measured at (PT1) point when $U_{control} = 0$

Pulses measured at (PT1) point when $U_{control} > 0$

Pulses measured at (PT1) point when $U_{control} < 0$

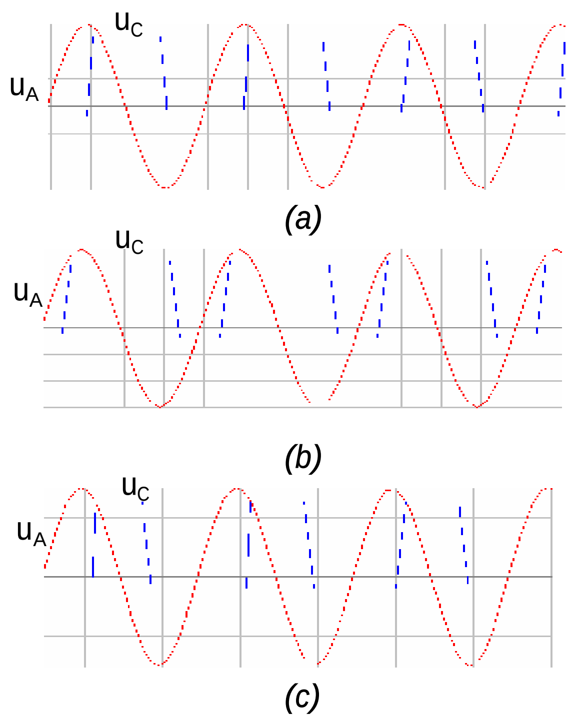

Fig. 5. The form of pulses mesured at (PT1) point.

From the simulation, we obtain considerations: If we consider the value of voltage crossing the zero point as the original value, we have:

- If the voltage $U_{control} = 0$, the firing angle $\alpha = 90^0$
- If the voltage $U_{control} < 0$, the firing angle $\alpha > 90^0$
- If the voltage $U_{control} > 0$, the firing angle $\alpha < 90^0$
- The construction of Pulse amplifier should be designed according with the parameters of thyristor valves.

3. Conclusion

The application of power electronic components for controlling in the above mentioned cases brings certain benefits. Comparing with the manual switching method or contactors switching controlling method, determining pulse for controlling switching thyristor has some advantages. They are not generating flashover, smooth voltage changing, not generating disturbances and harmonics.

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